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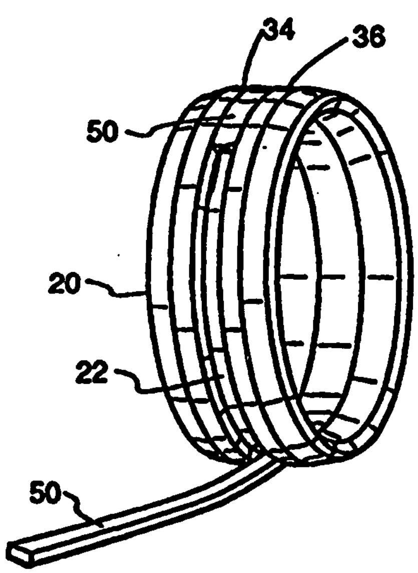

(57) Abstract: Articles and method for making composite articles, such as jewelry items, exemplified by finger rings, bracelets, earrings, body jewelry, etc., or medical, dental, and industrial devices or components are taught. A method of manufacturing the articles, including a substrate blank (20) comprising a first material, and an inlay comprising a second material (50), includes the steps of preheating the substrate; contacting a depression or groove (22) in a surface of the substrate with the second material; heating the second material at a point of contact with the substrate causing it to liquify and flow into the depression; and moving the point of contact along the depression in the surface of the substrate while continuously feeding and heating the second material to cause it to substantially fill the depression. An electron beam apparatus may be used to effect the heating.

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Method of Manufacturing Composite Articles Including Wear Resistant Jewelry

Field of the Invention

The present invention relates generally to an apparatus and method for manufacturing a composite article and to the article manufactured by that apparatus and method, and more particularly to an apparatus and method for manufacturing an article having a hard, wear-resistant component and a softer, more malleable component, such as articles made from "hard" metals and/or ceramic materials either alone or in combination with precious metals and jewels such that the hardened materials protect the softer precious metals and jewels from edge and detail wear down, including to jewelry items such as finger rings, bracelets, earrings, body jewelry, and the like, and medical or industrial devices or components.

BACKGROUND OF THE INVENTION

Jewelry has for centuries been made of soft materials such as gold, silver, platinum and other soft materials because such metals were malleable, and easily cast, forged, molded or otherwise formed. However, whereas such materials are relatively easy to form, shape and polish, they are equally subject to wear, scratching and other damage detracting from their longevity appearance and value, i.e., wearing down of edges to a smooth and rounded state.

More recently, science has produced other materials including tungsten, cemented carbide and high-tech ceramics that are much harder than the previously mentioned precious metals, and once formed, are virtually indestructible when used in

a normal jewelry wearing environment. One problem with such materials is that because of their hardness, they are very difficult to shape, and once formed, require special machining and/or grinding tools to alter their configuration and appearance. Accordingly, with the exception of articulated watch bands or housings for certain timepieces, such materials have historically not been used for articles of jewelry of the types mentioned above. However, I have recently discovered that through the use of powder metallurgy and sintering processes, such materials can be manufactured and used to provide faceted designs that were not heretofore practiced. Furthermore, such materials can be used to enhance and protect precious metals and gemstones in this jewelry setting.

In the process of fabricating parts from powdered metals, the most important step is one involving the welding together of the metallic powder to form a solid which will yield the proper shape and the properties required of the finished part. Although a good weld cannot be made between metals at room temperature by pressure alone, when the metal particles are relatively fine and plastic, a welding may occur that is satisfactory from the view point of handling, although little or no strength will be developed. Under pressure, at room temperature, metal powders that are plastic and relatively free from oxide films, may be compacted to form a solid of the desired shape having a strength (green strength) that allows the part to be handled. This result is often called cold-welding. The welding under pressure of the metal particles in order to form a solid blank of the shape desired, requires the use of pressures varying from 5 to 100 tons-per-square inch. Relatively light loads are used for the molding of the solder and more plastic metals, while pressures approaching 100 tons per square inch are necessary when maximum density is needed and when pressing relatively hard and fine metal powders such as those mentioned above are used in accordance with the present invention.

Commercial pressing is done in a variety of presses which may be of the single mechanical punch-press type or the double--action type of machine that allows pressing from two directions by moving upper and lower punches synchronized by means of cams. These machines also incorporate moveable core rods which make it possible to mold parts having long cores, assist in obtaining proper die fills and help in the ejection of the pressed parts.

The molding of small parts at great speeds and at relatively low pressures can be accomplished using the mechanical press. For example, mechanical presses can produce parts at the rate of 300 to 30,000 parts per hour. A satisfactory press should meet certain definite requirements among which are the following: (1) sufficient pressure should be available without excessive deflection of press members; (2) the press must have sufficient depth of fill to make a piece of required heights dependent upon the ratio of loose powder to the compressed volume, this being referred to as the compression ration; (3) a press should be designed with an upper or lower punch for each pressing level required in the finished part, although this may be taken care of by a die design with a shoulder or a spring mounted die which eliminates an extra punch in the press; and (4) a press should be designed to produce the number of parts required. The punches are usually made from an alloy of tungsten carbide or punched steel that can be hardened by oil quenching.

Heating of the cold-welded metal powder is called the "sintering" operation. The function of heat applied to the cold-welded powder is similar to the function of heat during a pressure-welding operation of steel in that it allows more freedom for the atoms and crystals; and it gives them an opportunity to re-crystalize and remedy the cold deformation or distortion within the cold pressed part. The heating of any cold-worked or deformed metal will result in re-crystallization and grain growth of the crystals or grains within the metal. This action is the same one that allows one to anneal any cold work-hardened metal and also allows one to pressure-weld metals. Therefore, a cold-welded powder will re-crystalize upon heating, and upon further heating, the new crystals will grow, thus the crystal grains become larger and fewer.

The sintering temperatures employed for the welding together of cold-pressed powders vary with the compressive loads used, the type of powders, and the strength required of the finished part. Compacts of powders utilized in accordance with the present invention are typically sintered at temperatures ranging from about 1000°C to in excess of 2000°C for approximately 30 minutes. When a mixture of different powders is to be sintered after pressing and the individual metal powders in the compact have markedly different melting points, the sintering temperatures used can be above the melting point of one of the component powders. The metal with a low melting point will thus become liquid; however, so long as the essential part or major metal powder is not molten, this practice may be employed. When the solid phase or powder

is soluble in the liquid metal, a marked delusion of the solid metal through the liquid phase may occur which will develop a good union between the particles and result in a high density.

Most cold-pressed and metal ceramic powders shrink during the sintering operation. In general, factors influencing shrinkage include particle size, pressure used in cold-welding, sintering temperature and time employed during the centering operation. Powders that are hard to compress will cold-shrink less during sintering. It is possible to control the amount of shrinkage that occurs. By careful selection of the powder and determination of the correct pressure for cold-forming it is possible to sinter so as to get minimal volume change. The amount of shrinkage or volume change should be determined so as to allow for this change in the design of the dies used in the process of fabricating a given shape.

The most common type of furnace employed for the sintering of pressed powders is the continuous type. This type of furnace usually contains three zones. The first zone warms the pressed parts and the protective atmosphere used in the furnaces purges the work of any air or oxygen that may be carried into the furnace by the work or trays. This zone may be cooled by water jackets surrounding the work. The second zone heats the work to the proper sintering temperature. The third zone has a water jacket that allows for rapid cooling of the work; and the same protective atmosphere surrounds the work during the cooling cycle.

Protective atmospheres are essential to the successful sintering of pressed powders. The object of such an atmosphere is to protect the pressed powders from oxidation which could prevent the successfully welding together of the particles of metal powder. Also if a reducing protective atmosphere is employed, any oxidation that may be present on the powder particles will be removed and thus aide in the process of welding. A common atmosphere used for the protection and reduction of oxides is hydrogen. Water vapor should be removed from the hydrogen gas by activated alumina dryers or refrigerators before it enters the furnace.

Many of the same problems and limitations experienced in the jewelry industry also pertain to the medical, dental, industrial, and scientific fields where there is a need for articles having particular structural and/or metallurgical or compositional properties have been difficult to manufacture.

Therefore there remains a need for articles having properties that are best met using composite materials, and methods, apparatus, and systems for making such articles.

SUMMARY OF THE INVENTION

The invention includes system, apparatus, and method for making composite articles. Such system and method are particularly well adapted to make composite articles having a hard, wear-resistant component and a softer, more malleable component. One such article is an article made from "hard" metals and/or ceramic materials either alone or in combination with precious metals and jewels such that the hardened materials protect the softer precious metals and jewels from edge and detail wear down. Jewelry items such as finger rings, bracelets, earrings, body jewelry, and the like, are one particular example of such articles. Medical, dental, and industrial devices or components are other examples of such articles. Furthermore, while the manufacturing method or process is particularly well suited to articles having a wear resistant component and a softer wearable component, the inventive method is not limited to such hard and soft constituents.

In one aspect, the invention provides a method of manufacturing a composite article including a substrate comprising a first material and an inlay comprising a second material. The method includes the steps of preheating the substrate; contacting a depression in a surface of the substrate with the second material; heating the second material at a point contact with the substrate causing it to liquify and flow into the depression; and moving the point of contact along the along the depression in the surface of the substrate while continuously feeding the second material and heating the second material at the point contact with the substrate to cause it to substantially fill the depression. The method may also optionally include generating the heat using an electron beam, applying a de-focused electron beam to the surface of the substrate to preheat the substrate, and applying a focused electron beam to the second material at the point contact with the substrate. Here, the process is advantageously carried out in a high-vacuum atmospheric environment.

The inventive method may be utilized with a cylindrical, spherical, or ring-shaped substrate having an outer surface and wherein the depression comprises a groove disposed circumferentially therein, and wherein the step of moving the point

of contact along the depression in the surface of the substrate includes rotating the substrate to move the point of contact along the along the groove.

In another aspect, the invention provides a method of manufacturing a composite article including a cylindrical, spherical, annular, or ring-shaped substrate comprising a first material and a metal wire comprising a second material, where the method includes the steps of: joining ends of the metal wire to form a metal ring or otherwise fabricating or machining to form a seamless metal ring or other article having an inner diameter greater than an outer diameter of the ring-shaped substrate; placing the metal ring over a groove disposed circumferentially in an outer surface; placing the substrate with the metal ring thereon on a mandrel; positioning the mandrel in a collet in an opening of a collet-block, the collet comprising a tapered hollow cylinder having a plurality of tines capable of being deformed radially inward to squeeze the metal ring into the groove of the ring-shaped substrate, the collet tapering from a maximum outer diameter proximal to a top end of the collet to a minimum outer diameter distal from the top end, and the opening in the collet-block comprising an inner diameter that tapers from a maximum proximal to a top surface of the collet-block to a minimum distal from the top surface; and forcing the collet with the mandrel positioned therein into the opening; so that the metal ring is squeezed into the groove in the ring-shaped substrate to form the composite article.

The invention further includes an object or article formed or manufactured using any of the inventive systems, apparatus, and/or method.

It is therefore a principal objective of the present invention to provide novel items formed from a combination of different materials and a system and method for making such items.

It is also a principal objective of the present invention to provide novel items of jewelry which are substantially immune from wear and ordinary damage suffered by similar prior art jewelry items of this type.

Another object of the present invention is to provide a novel method of combining "hard" metals with softer precious metals and jewels such that the hard materials shield and protect the softer materials from such wear and damage.

Still another objective of the present invention is to provide various designs for long-wearing jewelry that present a pleasant and unique appearance to the eye due to the unique reflection characteristics of the materials, facets and finishes used.

Yet another objective of the present invention is to provide a method for making jewelry of the type described above.

Briefly, articles of jewelry in accordance with the present invention, are made form sinterable metal and/or ceramic materials either alone or in combination with softer precious metals, stones, crystals or other materials suitable for use in jewelry. Such items of jewelry can be fabricated using various techniques and various combinations of materials, the presently preferred embodiments of which are described below.

Products made in accordance with the present invention have the advantage of being long-wearing and virtually indestructible while in normal use.

Another advantage of the present invention is that articles of jewelry made in accordance therewith maintain their luster for life and do not require frequent polishing.

Still another advantage of the present invention is that articles of jewelry made in accordance with the methods described are not subject to normal wear and thus, maintain their design details and value indefinitely.

Yet another advantage of the present invention is that numerous shapes and configurations of rings, earrings, bracelets and the like can be made using a variety of combinations of materials and colors of materials.

These and other objects and advantages of the present invention will no doubt become apparent to those skilled in the art after having read the following detailed description of the preferred embodiments illustrated in the several figures of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

These and various other features and advantages of the present invention will be apparent upon reading of the following detailed description in conjunction with the accompanying drawings, where:

Fig. 1 is a diagram schematically illustrating a press mold of a type used to make jewelry articles in accordance with the present invention;

Fig. 2 is a partially broken perspective view illustrating details of one form of a molded ring component in accordance with the present invention;

Fig. 3 is a perspective view illustrating one step in the preparation of a ring component in accordance with the present invention;

Fig. 4 is an illustration depicting a sintering step in accordance with the present invention;

Fig. 5 is a perspective view illustrating one method of combining a precious metal component with a hard metal and/or ceramic component in accordance with the present invention;

Fig. 6 is a flow chart illustrating steps followed to make jewelry in accordance with one embodiment of the present invention;

Figs. 7-14 are partial cross-sections taken through various embodiments illustrating alternative forms of rings made in accordance with the present invention;

Fig. 15 illustrates a unitary multifaceted hard metal/ceramic ring; and

Fig. 16 depicts a precious metal ring having a hard metal/ceramic band embedded therein to provide a protective outer wear surface.

Fig. 17 is a schematic side view of an embodiment of an apparatus for forming an article according to the present invention;

Fig. 18 is a schematic side view of an embodiment of an indexer of the apparatus of Fig. 17;

Fig. 19A and 19B are schematic side views of an embodiment of a mandrel for holding substrates in the apparatus of Fig. 17;

Fig. 20 is a flowchart of an embodiment of a process for manufacturing an article according to an embodiment of the present invention;

Fig. 21 is a schematic side view of another embodiment of an apparatus for forming an article according the present invention:

Fig. 22 is a schematic side view of an embodiment of a mandrel for holding substrates in the apparatus of Fig. 21; and

Fig. 23 is a flowchart of an embodiment of another process for manufacturing an article according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention includes system, apparatus, and method for making composite articles particularly to an apparatus and method for manufacturing an article having a hard, wear-resistant component and a softer, more malleable component. One such

article is an article made from "hard" metals and/or ceramic materials either alone or in combination with precious metals and jewels such that the hardened materials protect the softer precious metals and jewels from edge and detail wear down. Jewelry items such as finger rings, bracelets, earrings, body jewelry, and the like, are one particular example of such articles. Medical, dental, and industrial devices or components are other examples of such articles. Furthermore, while the manufacturing method or process is particularly well suited to articles having a wear resistant component and a softer wearable component, the inventive method is not limited to such hard and soft constituents. The broad applicability of the inventive articles and method for making such articles will become more apparent in light of the description and drawings provided herein.

Referring now to Fig. 1 of the drawing, a compressive mold is depicted at 10 including an annular cavity 12 generally illustrated and configured to receive a quantity of powdered, hard metal or high tech ceramic material that can be compressed and formed into an oversized "green" ring blank by the application of compressive forces applied by a mating press member 14. The mold 10 may be made in any configuration suitable for forming a particular annular or other shape, and the illustrated cavity is sized to as to produce an annular blank that, following shrinkage during subsequent processing, will have a predetermined size and configuration. Numerous types of powdered materials can be used in accordance with the present invention. One such powder includes the following constituents:

Nickel	2% to 10%
Cobalt	1% to 2%
Chromium or Chromium Carbide	0.5% to 3%
Tungsten or Tungsten Carbide	balance

Whereas in this example, Nickel and Cobalt are used as binder materials, other materials such as palodium, platinum, ruethenium, iridium and gold or alloys thereof, may also be used.

A ceramic composition might include:

ZIRCONIA (wt.%)

$ZrO_2 + HfO_2$	99%
SiO_2	0.20%
TiO_2	0.15%

Fe_2O_3	0.02%
SO_3	0.25%
LOI@1400°	0.30%

Whereas in this example, $ZrO_2 + HfO_2$ is used as the matrix material, silicon nitrides, silicon carbides and other similar materials may be used. In addition, various castoring agents may be included in the binding materials.

In Fig. 2 of the drawing, one configuration of a ring is illustrated at 20 and includes an annular external grove 22 formed in the outer surface thereof. As illustrated in the cross-section shown in the broken section at 24, the central-most portion 26 of the internal surface of the blank 20 is cylindrical with the outboard portions or facets 28 being angled relative thereto at angles typically in the range of from 1° to 30° relative to surface 26. The axial extremes of the cross-section of this embodiment are generally semicircular, as illustrated at 32, and the outer surface is configured to have cylindrical flats 34 and 36 on opposite sides of groove 22, and angled facets or flats 38 and 40 on the opposite sides thereof. As an alternative, the facets 38 and 40 may be configured to have multiple facet surfaces.

Once removed from the mold, the blank 20 is shaped by machinery filing, sanding, trimming or other appropriate techniques and may be burnished as illustrated in Fig. 3 to provide a smooth or textured surface, and made ready for sintering. Once prepared, the blank 20 is inserted into a sintering oven and the temperature raised as suggested by the arrows 42, to a suitable sintering temperature for a predetermined period of time during which the blank becomes hardened and shrinks to a size appreciably smaller than the size of the original green blank. However, as indicated above, the mold was sized taking into consideration the anticipated subsequent shrinkage and as a result, the ring stock after sintering, has a predetermined size. This, of course, implies that a different mold will be required for each ring size. As an alternative, it will be understood that the blank may be pressed to have a tubular configuration from which multiple rings may be severed and machined to appropriate individual sizes.

Following the sintering operation, the ring stock can be ground and finish polished, and when appropriate, have a selected precious metal and/or other material installed into the groove 22 as suggested by the laying in of the soft metal strip 50 depicted in Fig. 5 of the drawings. Once the metal strip 50 is suitably installed using

methods well known to jewelers, the assembly can be finish polished and made ready for market. It will, of course, be appreciated that other forms of materials can be inlaid into the groove 22. For example, preformed metal, stone, ceramic, shell or other segments could be glued or otherwise affixed to the ring. Preferably, such items will be slightly recessed below the surfaces of the facets 34 and 36 so as to be protected thereby.

Turning now to Fig. 6, which is a flow diagram illustrating the various steps followed in a preferred method of making a ring in accordance with the present invention. It will be noted that once a suitable press and mold has been prepared, the first step in making a ring or other object is to mix a predetermined combination of powdered metal or ceramic constituents to develop a sinterable metallic or ceramic powder. Once properly measured and disposed within the mold cavity, the power will be compressed by the mold to develop an oversized "green" ring blank that, although somewhat fragile, is stable enough to allow certain processing to be accomplished prior to sintering. For example, mold lines may be trimmed and smoothed, surfaces may be sanded or textured, facets may be smoothed etc. But once properly prepared, the next step is to load the blank at room temperature into a non-atmospheric sintering chamber and raise the temperature thereof to controlled temperatures, typically varying between 1000° C and 2000° C and then slowly cooled back to atmospheric temperature. Once cooled, the hardened ring stock or other blank configuration can be ground and polished to provide the hard metal or ceramic ring component. At this point, precious metal components, jewels and other decoration components may be affixed to the hard metal or ceramic part. One way to affix precious metal to the part is to use a brazing process and provide the components in varied shapes of wire sheet tubing or segments of other material that can be fabricated or forged into appropriate configurations and fit into the mating groove or channel 22. Fluxed or flux free gold or silver soldered compounds varying in color and purity between 50% and 99% purity can be applied on or around desired mating surfaces of the hard material as well as the precious metal or other materials after mechanically binding the parts together with round or flat wire or heat resistant custom fixtures. Prepared fixtures with parts are then loaded at room temperature into a non-atmospheric chamber and heated to controlled temperatures varying between 1000° to 2000° C and then allowed to cool down slowly to atmospheric temperature. This braising operation will not interfere with the previously

configured hard metal or ceramic components since their melting temperatures are substantially higher. An electron beam braising process described elsewhere may alternatively be used.

Another method of mating the precious metal or other components to the hardened component is to engineer the hardened component with various features such as holes, notches, slots, etc., such that various pre-shaped precious metal or other materials in mating configurations may be snapped or pressed, swaged or burnished into the hardened substructure. The resulting mechanical fit will hold the components together.

Still another method of mating the precious metal or other components to the hardened component is to bond them to the hardened part by means of one or two part hardening resin compounds that are heat and room temperature cured.

Also precious metals can be directly cast into cavities in hard metal or ceramic articles using lost wax techniques widely used in jewelry making.

But notwithstanding the process used to mate the components together, once the several components are in fact combined, the entire assembly can be finished and polished to complete manufacture of the ring or other article of jewelry.

Turning now to Figs. 7 through 14, various cross-sectional configurations of rings are depicted illustrating combinations of flats, facets, materials, inserts and component relationships. More specifically, in Fig. 7, a sintered metal part 60 is shown having a wide annular groove 62 formed in its outer surface and filled with a softer precious metal or other material 64. The top surface of material 64 may be flush with the top edges 66 of the facets 68 or may be recessed there beneath to enhance the protective function of the hardened metal part 60. This ring might have an axial length of 2-14 mm, a wall thickness of 1 - 2.8 mm and have facets at angles of from about 2% to 40% relative to the cylindrical surface 69.

In Fig. 8, a similar ring design is depicted, but in this case, utilizing a ceramic material as the hard surfaced part 70 with the sculpted precious metal part 72 being mounted within a groove 74 formed in the outer perimeter of the hard part 70. Note the different surface effects that can be achieved by increasing the angular relationship of the various facets and by depressing or recessing the surface of the insert 72.

Figs. 8-10 depict two-groove embodiments of both sintered metal and ceramic substructures at 76 and 78 respectively, each having precious metal or other inserts 80

and 82 formed in the annular grooves thereof, with the exterior surfaces of the inserts of the rings being treated differently to achieve substantially different visual effects. Note, that in either case, the "hard part" protects the softer precious metal part. Note that in this embodiment, the internal surface 83 is shown aligned rather than faceted. Other embodiments may be treated likewise.

In Fig. 11, a three-groove embodiment is depicted at 84.

Figs. 12-14 illustrate alternative embodiments in accordance with the present invention, wherein the hard metal or ceramic components are formed by two or more parts that are affixed together. For example, in Fig. 12, complementary annular sintered or ceramic parts 86 and 88 are provided with shallow bores 90 at several points around facing surfaces of the components, and a plurality of annular components 92 made of at least two materials 92 are sandwiched together and bored at intervals matching the bores 90, such that pins 94 may be extended through the bores in the ring components 92 with the ends thereof being extended into the bores 90 of the hardened ring components 86 and 88 to lend mechanical stability to the assembly. The various components 92 would, of course, be epoxied or otherwise bonded together.

In Figs. 13 and 14, three-part ring assemblies are illustrated at 96 and 98 respectively, with each being comprised of a central band 100 and 102 respectively, sandwiched between and mechanically bonded to a pair of exterior rings 104 and 105 respectively. In the case of the ring assembly illustrated in Fig. 13, for example, the exterior components 104 might be of sintered metal or of ceramic, while the interior band 100 might be of a precious metal, or even of a ceramic or sintered material. In the illustrated configuration, pockets 108 and azure holes 109 are formed in the interior band to receive gemstones 110 which are appropriately secured therein.

In the embodiment of Fig. 14, the interior band is depicted as being of a ceramic material sandwiched between and mechanically interlocked to exterior bands 106 made of sintered material or even precious metal, while the gemstones 112 are set in a precious metal 114.

Fig. 15 depicts at 120 a multifaceted unitary ring configuration made of a single, hard metal or ceramic substance. The six highly polished facets 121 on the outer surface of the ring create a unique design and visual impression heretofore not possible using prior art rings making techniques and technologies, because if such configuration

had been made, the peaks 122 would have quickly been eroded, destroying the esthetic appearance of the ring.

In Fig. 16 of the drawing, still another alternative embodiment is depicted wherein a ring made primarily of precious metal 123 includes an annular insert 124 embedded therein and extending above the uppermost surface of the precious metal component to provide a protective and esthetically pleasing insert.

Alternatively, one or more holes or cavities may be provided around the ring for receiving precious metals and/or set stones.

The principal concept of this invention is the provision of an ultra durable hard metal or high tech ceramic type of jewelry that may or may not incorporate precious metals and/or precious gem stones. The invention also provides a unique jewelry manufacturing process that combines hard metals with precious metals in a manner such that the precious metals are flush or recessed slightly below the outer most surfaces of the hard metals over the outer wear surfaces to achieve maximum abrasion and corrosion resistance. This is not to preclude the use of protruding precious metal or gemstone components, but in such cases the protruding components would not be protected by the harder materials. The invention involves the provision of jewelry items made from super hard metals such as tungsten and cemented carbide and high tech ceramics of various colors processed into a predetermined shape then sintered in a furnace and ground and polished into finished form. These items may be shaped into concentric circular ring shapes of various sizes and profiles or individual parts may be ground into shapes that can be bonded to a precious metal substrate so as to protect the softer substrate. The hard metal circular designs encompass all types of profiles and cross-sectional configurations for rings, earrings and bracelets. Hard metal items may be processed with various sized and shaped openings distributed around the parameter, with other objects of precious metal gem stones or the like secured into the various openings for cosmetic purposes. Gem stones set in precious metal may be secured into said openings for protection from scratching and daily wear.

Another configuration similar to that depicted in Fig. 11 might include several concentric rings of varying widths and thicknesses of precious metal or other material sandwiched between concentric rings of varying widths, thicknesses and profiles of hard metal. The components are assembled and bonded together with the softer precious metal surfaces being recessed below the adjacent surfaces of the hard metal,

thereby causing all of the outer wear surfaces to be protected by the super hard metals surfaces.

Annular rings, earrings and bracelets may also be fashioned by combining variations of precious metal bands with the protective hard metal individual parts bonded onto and into slots or grooves or flat areas of the substrate precious metal bands. These hard metal parts will be positioned to give maximum protections to the precious metal parts.

Articles of jewelry may be created using symmetrical or asymmetrical grid-type patterns. Machined hard metal parts of varying shapes and sizes may be assembled and bonded onto or into a precious metal substrate designed where precious metal is recessed for maximum durability.

Articles of jewelry in accordance with the present invention may be made with various types of hard metals and precious metals where the hard metal is used for both esthetic and structural strength purposes. Hard metal rods of varying shapes and sizes may be used in conjunction with precious metals to create a unique jewelry design having a very high structural strength. Articles of jewelry may be made entirely of hard metal or a combination of hard metal and precious metal where the cosmetic surfaces of the hard metal are ground to have a faceted look. These facets are unique to hard metal configurations in that precious metal is too soft and facet edges formed in such soft metals would wear off readily with normal everyday use.

The present invention has been described above as being comprised of a molded hard metal or ceramic component configured to protect a precious metal or other component; however, it will be appreciated that the invention is equally applicable to a multifaceted, highly polished jewelry item made solely of the hard metal composition or ceramic composition.

Furthermore, the present invention relates to a method of making jewelry wherein a rough molded and sintered part is subsequently machined to produce multiple facets and surfaces that can be highly polished to provide an unusually shiny ring surface that is highly resistant to abrasion, wear and corrosion. As used in this description, the term facet is intended to include both cylindrical and frusto conical surfaces as well as planar or flat surfaces.

Having now described several embodiments of the invention, we now highlight a few exemplary embodiments of the invention.

In a first aspect, the invention provides an article, such as an item of jewelry, made of material selected from the group consisting of sintered metals and ceramics and having at least one highly polished facet formed on an outer surface thereof. In a second aspect, the invention provides an item of jewelry configured as an annular band having at least one annular groove formed in the outermost surface thereof and includes an insert of precious metal disposed within the groove. In a third aspect, the invention provides an item of jewelry wherein the outer surface of the inset of precious metal is recessed below adjacent extremities of the annular band. In a fourth aspect, the invention provides an item of jewelry wherein at least one gemstone is set in the insert of precious metal, the outermost surface of the gemstone being recessed beneath the adjacent extremities of the annular band. In a fifth aspect, the invention provides an item of jewelry wherein at least one gemstone is set in the insert of precious metal. In a sixth aspect, the invention provides an item of jewelry wherein at least one gemstone is set in a cavity in the band. In a seventh aspect, the invention provides an item of jewelry configured as an annular band embedded in a concentric band of precious metal and having its outermost circumference protruding above the outermost circumference of the concentric band. In an eighth aspect, the invention provides an item of jewelry wherein the annular band is comprised of at least two components axially separated by and joined together by at least one annular band of precious metal. In a ninth aspect, the invention provides an item of jewelry wherein the axially separated annular bands are joined together by a plurality of concentric annular bands made of disparate materials. In a tenth aspect, the invention provides an item of jewelry wherein the annular band includes at least two grooves formed in the outer surface thereof, the two grooves being at least partially filled with a material other than that of the annular band.

In an eleventh aspect, the invention provides a method of providing an article, such as for example, an item of jewelry, where the method comprises the steps of: providing a pressure mold having a cavity of predetermined configuration formed therein; providing a mixture of two or more powdered materials that can be solidified upon the application of pressure and heat; depositing a predetermined quantity of the mixture of powdered materials within the cavity; compressing the quantity of powdered material to form a blank; and sintering the blank to form at least a component of the item of jewelry. This method may further be defined such that the item of jewelry is in the form of an annular band having a groove formed in the outer surface thereof, and

further comprising the step of affixing a material within the outer groove, the outer surface thereof being recessed beneath the bounding edges of the groove. This method may be even further defined such that the affixed material is a precious metal that is affixed to the annular ring by brazing. The method may optionally be further defined such that the affixed material is affixed to the annular blank through the use of resinous materials. In a fifteenth aspect, the method may also include the step of finish polishing at least one surface of the annular blank. The method may be further defined such that the annular band has a plurality of facets formed in an outer surface thereof. In a seventeenth aspect, the invention may be further defined such that the affixed material is affixed to the annular blank by a mechanical interlocking of parts. In yet an eighteenth aspect, the inventive method may provide that the blank is severed to form a plurality of sub-blanks, each forming at least a component of the item of jewelry. In a nineteenth aspect, the method may further comprise affixing a gemstone or piece of precious metal to the item of jewelry. In another aspect, the method is further defined such that the component has a plurality of facets formed in an outer surface thereof.

While the certain embodiments of the article and method have been described with particular emphasis on jewelry items and articles, it is understood that neither the inventive article nor the apparatus or method for making the inventive article are limited to jewelry items but extends to all articles having the physical and materials properties described herein.

<u>**Alternative Embodiments**</u>

The invention also provides system, apparatus, and method or process for creating objects or articles, particularly composite articles, using wear-resistant or other materials, such as tungsten-carbide, poly or mono crystalline ceramics, and mixtures or alloys thereof. In one embodiment, the process is directed to the manufacture of articles having a circular, spherical, or cylindrical cross-section, such as items of jewelry or rings. In some embodiments, the circular, sphered or cylindrical article will b e combined with other shapes and/or deformed after fabrication so that the final article has a different shape than circular, spherical or cylindrical. The manufactured articles, particularly items of jewelry items, typically have inlays of a precious metal, such as gold, platinum, or alloys thereof. Characteristics and examples of some such articles and materials have been described elsewhere in the specification. However, it will be

clear that the process described is not limited to the manufacture of items of jewelry, but may generally be applied to fabricating a variety of articles.

In a first embodiment of a process according to the present invention, a procedure is provided that permits the inlay of a metal having a lower melting point into one or more grooves or depressions in an underlying support or substrate. For example, the procedure is applicable to inlaying a precious or semi-precious metal such as gold into a groove in a sintered tungsten-carbide or ceramic ring. By lower melting point it is meant a metal (or alloy) having a temperature of fusion that is low relative to that of the material of the substrate.

An apparatus and process for manufacturing an article according to the present invention will now be described with reference to FIG. 17 through FIG. 20. FIG. 17 is a schematic side view of an embodiment of a vacuum deposition system 100 for forming an article 105 according the present invention. FIG. 18 is a detailed view of an indexer 110 of the system 100 of FIG. 17. FIG. 19A and 19B are schematic side views of an embodiment of a mandrel 115 for holding substrates 120. FIG. 20 is a flowchart of an embodiment of a process 125 for manufacturing an article 105 according to an embodiment of the present invention.

The process 125 involves rotating a substrate 120 of the article 105 being manufactured, such as a ring-shaped substrate, inside the vacuum deposition system 100 where a liquid cooled mandrel 115 covered by an electrically conductive sheath 135. In one embodiment, a number of substrates 120 are stacked along the mandrel 115 with thin washer shaped separators 140 to provide alternating substrate, separator, substrate, and the like. The electrical conductive sheath 135 can be made, for example, of extruded graphite or a metal-coated ceramic material such as aluminum oxide or mulite.

A spool 145 of metal wire 150 contained within the deposition system 100 is delivered via a delivery mechanism 160 through a nozzle 165 just behind a point or location 170 where an electron beam 175 (e-beam) is focused to strike the rotating substrate 120.

During an initial warm-up stage (Step 185) of the process 125 the electron beam 175 is deliberately de-focused (Step 190) to preheat (Step 195) the substrate 120. Typically the substrate 120 is preheated to a temperature of between about 300 to about 600° F (150 to 300°C).

After preheating, the electron beam 175 is finely focused (Step 200) at a focal point 205 coincident with the width of a grooved portion 210 having a recessed groove 215 or depression on a surface of the substrate120. Simultaneously, the metal wire 150 is fed through the nozzle 165 into the path of the focused electron beam 175, and as a result of the impact of the electrons from the electron beam, heated causing it to virtually instantaneously liquify (Step 225) and flow into the groove 215 of the substrate 120. Wire 150 is continuously fed and heated until an adequate amount of metal has been deposited or applied to the groove (Step 230). The energy in electron beam 175 is then gradually reduced (Step 235) to allow solidification of the metal in the groove 215 and cooling of the article 105.

The mandrel 115 is then stepped or indexed (Step 245) using the indexer 110 shown in FIG. 18 to a center of the grooved portion 210 of the next substrate 120, and the process 125 repeated (Steps 185 to 245) until all substrates have been metalized, that is until all substrates have had metal deposited into the groove 215.

Preferably, a temperature sensor 255, such as an optical pyrometer, is provided within vacuum deposition system 100 to read the temperature of the substrate 120 and to provide the temperature to a control program (not shown) that precisely controls the delivery mechanism 160, indexing of the indexer 110 and the power and focus of the electron beam 175 to produce an article 105 having a uniform and seamless band of metal about the substrate 120. Alternatively, if the degree of uniformity is not critical, a simple open loop control (not shown) in which the metal wire 150 is fed at a constant rate, the indexer 110 indexed, and the electron beam 175 is powered up and focused at regular intervals, can be provided rather than the feedback control using temperature, but is not preferred.

Because a sensing lens 265 or window of the temperature sensor 255 is susceptible to metal deposition resulting from vaporization of some of the molten metal in the vacuum deposition system, a lens shield 270 may advantageously be interposed between the sensing lens 265 and the substrate 120. The shield 270 can be made from Mylar or other clear (optically transparent) material placed in between the sensing lens 265 and the substrate 120. Preferably, the lens shield 270 is a thin strip or tape of material which is continuously moved past sensing lens 265 of the temperature sensor 255 during the metalization process 125, thus allowing the temperature sensor to always read the temperature accurately. Alternatively or in addition thereto, the sensor lens

265 may be covered by a shutter or other movable cover 275 so that the sensor lens is covered at all times while liquid or gaseous metal is present in the system 100. The cover 275 is moved away from the sensor lens 265 during the preheating phase (step 195) to ensure that preheat temperature is reached before the metalization step begins.

As already described, this first process 125 for depositing a layer of material having a lower melting point than the substrate 120 can only be used with certain materials. When the melting temperature of the inlay material is higher than the substrate 120, heating the substrate and/or depositing the molten metal may, at the very least, damage or deform the substrate. Hence, an alternative second process 285 has been developed for inlaying materials having a high melting temperature, such as platinum, or alloys thereof, onto a substrate 120. Such high temperature materials cannot be directly melted into the groove 215 by the first process 125 described above because their melting temperature is as high or higher than the sintering temperature or temperature of fusion of the substrate. This second process 285 can also be used where the melting temperature of the inlay material is below the melting or sintering temperature of the substrate 120.

The second process 285 involves the fabrication of the article 105 using swaging and braising operations. Generally, the metal wire 150 is soldered or welded to form a joint-less metal ring 290 (or otherwise fabricating or machining to form a seamless metal ring or other article) that is then squeezed or swaged onto a sintered substrate 120. A braising material (not shown) having a melting point lower than both the metal ring 290 and the substrate 120 is applied to a junction (not shown) between the metal ring and the substrate to wick into the junction by capillary action, thereby forming a solid unitary article 105 having substantially no gaps or interstitial recesses between the metal ring and the substrate.

FIG. 21 shows a schematic diagram of an exemplary embodiment of a mechanical press 300 suitable for swaging or squeezing the metal ring 290 onto the substrate 120 according the second process 285 of the present invention. The press 300 generally includes several rods or mandrels 305 to hold the substrate 120 with the metal ring 290 disposed thereabout, one or more threaded, tapered top collets 310 into which the mandrel is placed, one or more collet-blocks 315 having tapered openings 320 into which the collet is forced to squeeze or swage the metal ring to the substrate and a pneumatic or hydraulic power cylinder 325 to force the collet into the opening in the

collet block. In operation, air or hydraulic fluid from a pressurized supply 335 is admitted to the power cylinder 325 through a manual or electronic valve 340. In the embodiment shown in FIG. 21 the press 300 further includes a hydraulic fluid cylinder 345 to which air is applied and a pneumatic multiplier 350 to convert the relatively low pressure air to a higher hydraulic fluid pressure. Pneumatic multipliers 350 typically raise the pressure of a hydraulic fluid to a pressure from 4 to 12 times that of the pneumatic air. For example, supplying 50 pounds per square inch (psi) of air can produce 600 psi in a hydraulic fluid supplied to the collet-blocks 315.

Preferably the mandrel 305, shown in detail in FIG. 22, has an outer diameter (OD) sized to re-enforce or support the substrate 120 during the manufacturing process 285. More preferably, the mandrel 305 is of an expanding type that has an OD that can be adjusted to be substantially the same as the inner diameter (ID) of the substrate 120 to apply a counter-force directed radially outward from the substrate thereby preventing it from deforming or cracking when force is applied to the OD of the substrate.

The top collets 310 have a generally hollow cylindrical shape and are threaded at one end to engage a threaded fitting inside the opening 320 in the collet-blocks 315. The collets 310 are tapered from an OD larger than the metal ring 290 to a minimum OD near the threaded end, and are segmented axially to form three or more arcuate prongs or tines 355 that are deformed radially inward as the top collet is pulled into the opening 320 in the collet-block 315. The collet-block 315 also tapers from an ID slightly larger than the OD of the metal ring 290 to an minimum ID slightly smaller than the OD of the substrate 120. As the top collet 310, with the mandrel 305 positioned therein, is pulled into the opening 320 in the collet-block 315, the arcuate tines 355of the collet move radially inward to swage the metal ring 290 to the substrate 120. This can be accomplished either by pulling the top collet 310 down through the opening 320 in the collet-block 315 or by raising the collet-block over the top collet.

A process for manufacturing an article 105 according to the present invention will now be described with reference to FIG. 23. FIG. 23 is a flowchart of steps for manufacturing the article according to the second process 285. .

In an initial step, (step 365) ends of a metal wire are joined and soldered to form a joint-less metal ring 290 having an ID larger than an OD of the substrate 120. The metal ring 290 is placed over the groove 215 in the substrate 120. (step 370). The substrate 120, with the metal ring 290 assembled thereon, is then place on the

mandrel 305. (step 375). Optionally, if the mandrel 305 is of the expanding type, the OD of the mandrel adjusted to be substantially the same as the ID of the substrate 120. (step 378) The mandrel 305, with the metal ring 290 and substrate 120 assembly thereon is positioned in the top collet 310 in the collet-block 315. (step 380). The pressure supply valve 340 is opened admitting pressurized air or hydraulic fluid to the power cylinder 325 forcing the top collet 310 through the opening 320 in the collet-block 315 and swaging the metal ring 290 to the substrate 120 (step 385). The pressure supply valve 340 is closed and the mandrel 305 removed (step 390). In a preferred embodiment, the process 285 is a multi-step process in which the top collet 310 with the mandrel 305 therein is moved through a sequence of collet-blocks 315 having successively smaller minimum ids so as to yield a snug fit of the metal ring 290 onto the substrate 120. For example, in the embodiment of the mechanical press 300 shown in FIG. 21, the process can be a three step process in which the three collet-blocks 315 shown have openings 320 that are large, medium or small relative to one another.

After the metal ring 290 is swaged to the substrate, the assembly is removed from the mandrel 305, optionally but desirably checked for cracks and then cleaned (step 395) prior to beginning the braising process.

A preferred braising process (step 400) uses an electron beam 175 similar to that described above in the first process 125 but substituting silver, gold or a eutectic alloy wire 150 as a braising material to bond the metal ring 290 and the substrate 120 together rather than to fill the groove 215.

In an alternative braising step (not shown), the braising can be accomplished by applying a braising material near the groove 215 in the assembled metal ring 290 and substrate 120 and heating the assembly in a vacuum chamber or other oxygen free environment. The assembly is slowly raised to the proper temperature and then slowly cooled to complete the braising operation. In yet another alternative braising step (not shown), the braising can be accomplished by depositing a thin strip or small amount of braising material in the groove 215 prior to the swaging operation and then heating the assembly as described above.

After the metalizing process (steps 365 to 400) is completed, the article 105 is mounted into a fixture (not shown) in a lathe (not shown) and the excess metal removed (step 405).

Although described relative to a process for flowing molten precious or semiprecious metal into a groove 215 in a ring-shaped substrate 120, the inventive process 125 is not so restricted. It may, for example, be utilized for any application in which it is desired to deposit one metal material onto a substrate, independent of the form or composition of the substrate. Examples of such alternative applications include: medical devices and implants, dental devices and implants, industrial and electronic devices and components, and so forth.

It is to be understood that even though numerous characteristics and advantages of certain embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

WHAT IS CLAIMED IS:

1. A method of manufacturing a composite article including a substrate comprising a first material and an inlay comprising a second material, the method comprising steps of:

(a) preheating the substrate;

(b) contacting a depression in a surface of the substrate with the second material;

(c) heating the second material at a point contact with the substrate causing it to liquify and flow into the depression; and

(d) moving the point of contact along the along the depression in the surface of the substrate while continuously feeding the second material and heating the second material at the point contact with the substrate to cause it to substantially fill the depression.

2. A method according to claim 1 wherein heat is generated using an electron beam, and wherein step (a) comprises the step of applying a de-focused electron beam to the surface of the substrate in a vacuum environment to preheat the substrate and step (c) comprises the step of applying a focused electron beam to the second material at the point contact with the substrate; wherein said de-focused electron beam may be from the same electron beam source as said focused electron beam or from a different source.

3. A method according to claim 1 wherein step (a) comprises the step of preheating the substrate to a temperature within about 90% of the temperature of fusion of the second material.

4. A method according to claim 1 wherein step (c) comprises the step of heating the second material to a temperature equal to or greater than the temperature of fusion of the second material.

5. A method according to claim 1 wherein the inlay material comprises a metal wire and wherein step (d) comprises the step of continuously feeding the metal wire into the depression in the surface of the substrate.

6. A method according to claim 1 wherein the substrate comprises a ring-shaped substrate having an outer surface and wherein the depression comprises a groove disposed circumferentially therein, and wherein step (d) comprises the step of rotating the ring shaped substrate to move the point of contact along the groove.

7. A method according to claim 6 wherein a plurality of ring-shaped substrates are held coaxially, spaced apart on cylindrical mandrel, and wherein the method comprises the further steps of:

(e) gradually reducing energy of the electron beam;

(f) moving the mandrel axially to index from one of the ring-shaped substrates to another of the ring-shaped substrates;

(g) repeating steps (a) to (e); and

(h) repeating steps (a) to (g) until grooves in each of the plurality of ring-shaped substrates have been substantially filled with inlay material.

8. A method according to claim 6 further comprising the step of removing excess material from the groove using a lathe.

9. A method according to claim 1 wherein the first material comprises a ceramic and the second material comprises a precious metal, and wherein step (c) comprises heating the second material to a temperature greater than a temperature of fusion of the precious metal and below a sintering temperature of the ceramic.

10. A method of manufacturing a composite article including a ring-shaped substrate comprising a first material and a metal wire comprising a second material, the method comprising steps of:

(a) joining ends of the metal wire to form a metal ring having an inner diameter greater than an outer diameter of the ring-shaped substrate;

(b) placing the metal ring over a groove disposed circumferentially in an outer surface;

(c) placing the substrate with the metal ring thereon on a mandrel;

(d) positioning the mandrel in a collet in an opening of a collet-block, the collet comprising a tapered hollow cylinder having a plurality of tines capable of being deformed radially inward to squeeze the metal ring into the groove the ring-shaped substrate, the collet tapering from a maximum outer diameter proximal to a top end of the collet to a minimum outer diameter distal from the top end, and the opening in the collet-block comprising a inner diameter that tapers from a maximum

proximal to a top surface of the collet-block to a minimum distal from the top surface; and

(e) forcing the collet with the mandrel positioned therein into the opening,

whereby the metal ring is squeezed into the groove in the ring-shaped substrate to form the composite article.

11. A method according to claim 10 comprising the further step (f) of braising the metal ring to the ring-shaped substrate using a braising material.

12. A method according to claim 11 wherein the ring-shaped substrate and the metal ring comprise fusible material, and wherein step (f) comprises the step of heating the braising material to a temperature greater than a temperature of fusion of the braising material and below temperatures of fusion of the ring-shaped substrate and the metal ring.

13. A method according to claim 11 wherein the ring-shaped substrate comprises a ceramic, and wherein step (f) comprises the step of heating the braising material to a temperature greater than a temperature of fusion of the braising material and below a temperature of fusion of the metal ring and a sintering temperature of the ceramic.

14. A method according to claim 11, wherein braising material comprises a wire of braising material, and wherein step (f) comprises the steps of:

(f)(i) contacting a junction between in the ring-shaped substrate and the metal ring with the wire of braising material;

(f)(ii) heating the wire of braising material at a point contact with the junction causing the braising material to liquify and flow into the junction; and

(f)(iii) moving the point of contact along the along the junction while continuously feeding the wire of braising material and heating the wire of braising material at the point of contact with the ring-shaped substrate to cause it to substantially fill interstitial gaps between in the ring-shaped substrate and the metal ring.

15. A method according to claim 10 further comprising the step of removing the composite article from the mandrel, inspecting the ring-shaped substrate and cleaning the composite article.

16. A method according to claim 10 further comprising the step of removing excess material from the groove using a lathe.

17. A method of providing an article comprising:

providing a pressure mold having a cavity of predetermined configuration formed therein;

providing a mixture of two or more powdered materials that can be solidified upon the application of pressure and heat;

depositing a predetermined quantity of said mixture of powdered materials within said cavity;

compressing said quantity of powdered material to form a blank; and

sintering said blank to form at least a component of said article.

18. A method as recited in claim 17 wherein said article is in the form of an annular band having a groove formed in the outer surface thereof, and further comprising the step of affixing a material within said outer groove, the outer surface thereof being recessed beneath the bounding edges of said groove.

19. A method as recited in claim 18 wherein said affixed material is a precious metal that is affixed to said annular ring by brazing.

20. A method as recited in claim 18 wherein said affixed material is affixed to said annular blank through the use of resinous materials.

21. A method as recited in claim 18 and further comprising the step of finish polishing at least one surface of said annular blank.

22. A method as recited in claim 18 wherein said annular band has a plurality of facets formed in an outer surface thereof.

23. A method as recited in claim 18 wherein said affixed material is affixed to said annular blank by a mechanical interlocking of parts.

24. A method as recited in claim 17 wherein said blank is severed to form a plurality of sub-blanks, each forming at least a component of said article.

25. A method as recited in claim 17 and further comprising affixing a gemstone or piece of precious metal to said article.

26. A method as recited in claim 17 wherein said component has a plurality of facets formed in an outer surface thereof.

27. The method as recited in claim 17 wherein said article is an item of jewelry.

AMENDED CLAIMS

[received by the International Bureau on 04 March 2001 (04.03.01);
original claim 10 amended; claims 28-36 added;
remaining claims unchanged (6 pages)]

5. A method according to claim 1 wherein the inlay material comprises a metal wire and wherein step (d) comprises the step of continuously feeding the metal wire into the depression in the surface of the substrate.

6. A method according to claim 1 wherein the substrate comprises a ring-shaped substrate having an outer surface and wherein the depression comprises a groove disposed circumferentially therein, and wherein step (d) comprises the step of rotating the ring shaped substrate to move the point of contact along the groove.

7. A method according to claim 6 wherein a plurality of ring-shaped substrates are held coaxially, spaced apart on cylindrical mandrel, and wherein the method comprises the further steps of:

(e) gradually reducing energy of the electron beam;

(f) moving the mandrel axially to index from one of the ring-shaped substrates to another of the ring-shaped substrates;

(g) repeating steps (a) to (e); and

(h) repeating steps (a) to (g) until grooves in each of the plurality of ring-shaped substrates have been substantially filled with inlay material.

8. A method according to claim 6 further comprising the step of removing excess material from the groove using a lathe.

9. A method according to claim 1 wherein the first material comprises a ceramic and the second material comprises a precious metal, and wherein step (c) comprises heating the second material to a temperature greater than a temperature of fusion of the precious metal and below a sintering temperature of the ceramic.

10. A method of manufacturing a composite article including a ring-shaped substrate comprising a first material and a metal wire comprising a second material, the method comprising steps of:

(a) joining ends of the metal wire to form a metal ring having an inner diameter greater than an outer diameter of the ring-shaped substrate;

(b) placing the metal ring over a groove disposed circumferentially in an outer surface;

(c) placing the substrate with the metal ring thereon on a mandrel;

(d) positioning the mandrel in a collet in an opening of a collet-block, the collet comprising a tapered hollow cylinder having a plurality of tines capable of being deformed radially inward to squeeze the metal ring into the groove the ring-shaped substrate, the collet tapering from a maximum outer diameter proximal to a top end of the collet to a minimum outer diameter distal from the top end, and the opening in the collet-block comprising a inner diameter that tapers from a maximum proximal to a top surface of the collet-block to a minimum distal from the top surface; and

(e) forcing the collet with the mandrel positioned therein into the opening, so that the metal ring is squeezed into the groove in the ring-shaped substrate to form the composite article.

11. A method according to claim 10 comprising the further step (f) of braising the metal ring to the ring-shaped substrate using a braising material.

12. A method according to claim 11 wherein the ring-shaped substrate and the metal ring comprise fusible material, and wherein step (f) comprises the step of heating the braising material to a temperature greater than a temperature of fusion of the braising material and below temperatures of fusion of the ring-shaped substrate and the metal ring.

13. A method according to claim 11 wherein the ring-shaped substrate comprises a ceramic, and wherein step (f) comprises the step of heating the braising material to a temperature greater than a temperature of fusion of the braising material and below a temperature of fusion of the metal ring and a sintering temperature of the ceramic.

28. A method of manufacturing a composite ring-shaped jewelry article including a substrate comprising a first material and an metal wire inlay comprising a second material different from the first and having a melting point that is lower than a melting point of the first material, the method comprising steps of:

(a) preheating the surface of the first material substrate using a de-focused electron beam applied to the surface in a vacuum environment to a temperature lower than its melting point;

(b) contacting a depression in a surface of the substrate with the second material;

(c) heating the second material at a point contact with the substrate by applying a focused electron beam to the second material at the point contact with the substrate causing the second material to liquify and flow into the depression without reaching the melting point of the first material;

(d) moving the point of contact of the second material with the substrate along the depression in the surface of the substrate comprising a groove disposed circumferentially around the ring-shaped article by rotating the substrate multiple revolutions while continuously feeding the metal wire and heating the metal wire at the point contact with the substrate to cause it to liquify and as the substrate is rotated and metal wire is fed and liquified to substantially fill the depression.

29. A method according to claim 28, wherein the first material comprises a ceramic and the second material comprises a precious metal, and wherein the step of heating the second material comprises heating the second material to a temperature greater than a temperature of fusion of the precious metal and below a sintering temperature of the ceramic.

30. A method according to claim 28, wherein the second material comprises gold.

31. A method according to claim 28, wherein the first material comprises a ceramic material and the second material comprises gold.

32. A method according to claim 29, wherein the precious metal comprises gold.

33. A method according to claim 28, wherein a plurality of ring-shaped substrates are held coaxially, spaced apart on cylindrical mandrel, and wherein the method comprises the further steps of:

(e) gradually reducing energy of the electron beam after filling the depression of one of the ring-shaped substrates;

(f) moving the mandrel axially to index from one of the ring-shaped substrates to another of the ring-shaped substrates; and

(g) repeating steps (a) to (g) until grooves in each of the plurality of ring-shaped substrates have been substantially filled with inlay material.

34. A method according to claim 28, wherein the first material comprises a ceramic and the second material comprises a precious metal, and wherein the step of heating the second material comprises heating the second material to a temperature greater than a temperature of fusion of the precious metal and below a sintering temperature of the ceramic.

35. A method of manufacturing a plurality of ring-shaped jewelry articles, each including a ceramic substrate and a gold metal alloy inlay, the method comprising steps of:

(a) holding, a plurality of ring-shaped jewelry articles coaxially, spaced apart on cylindrical mandrel;

(b) preheating a surface of at least one of the ceramic substrate using a de-focused electron beam in a vacuum environment to a temperature lower than the sintering temperature of the ceramic;

(c) contacting a cylindrical depression in a surface of the ceramic with a terminal portion of a gold wire;

(d) heating the gold metal alloy at a point contact with the ceramic by applying a focused electron beam to the gold at the point contact with the ceramic causing the gold to liquify and flow into the depression without reaching the sintering temperature of the first material;

(e) spinning the ceramic substrate to move the point of contact of the gold wire with the ceramic substrate along the depression while continuously feeding the gold wire and heating the gold wire at the point contact with the ceramic substrate to cause the gold to liquify at the point of contact and solidify shortly thereafter without migrating out of the depression until the gold at least substantially fills the depression;

(f) gradually reducing energy of the electron beam after filling the depression of one of the ring-shaped substrates and before beginning filling another ring-shaped substrate; and

(g) moving the mandrel axially to index from one of the ring-shaped substrates to another of the ring-shaped substrates;

(h) repeating the above steps until grooves in each of the plurality of ring-shaped substrates have been filled with gold inlay material;

(i) removing excess material from the groove of each of the articles using a lathe; and

(j) polishing the articles to produce a polished jewelry surface.

36. A method of manufacturing a jewelry ring having a ring-shaped substrate comprising a fusible ceramic material and a precious metal inlay wire or band, the method comprising steps of:

(a) joining ends of the precious metal wire to form a metal ring having an inner diameter greater than an outer diameter surface of the ring-shaped substrate;

(b) placing the metal ring over a groove disposed circumferentially in an outer surface;

(c) placing the substrate with the metal ring thereon on a mandrel;

(d) positioning the mandrel in a collet in an opening of a collet-block, the collet comprising a tapered hollow cylinder having a plurality of tines capable of being deformed radially inward to squeeze the metal ring into the groove the ring-shaped substrate, the collet tapering from a maximum outer diameter proximal to a top end of the collet to a minimum outer diameter distal from the top end, and the opening in the collet-block comprising a inner diameter that tapers from a maximum proximal to a top surface of the collet-block to a minimum distal from the top surface;

(e) forcing the collet with the mandrel positioned therein into the opening so that the metal ring is squeezed into the groove in the ring-shaped substrate to form the composite article;

(f) braising the precious metal ring or band to the ring-shaped substrate using a braising material by heating the braising material to a temperature greater than a temperature of fusion of the braising material and below temperatures of sintering of the ring-shaped substrate and the fusion of the precious metal ring, the braising further comprising:

(f)(i) contacting a junction between in the ring-shaped substrate and the metal ring with the wire of braising material;

(f)(ii) heating the wire of braising material at a point contact with the junction causing the braising material to liquify and flow into the junction; and

(f)(iii) moving the point of contact along the along the junction while continuously feeding the wire of braising material and heating the wire of braising material at the point of contact with the ring-shaped substrate to cause it to substantially fill interstitial gaps between in the ring-shaped substrate and the metal ring.

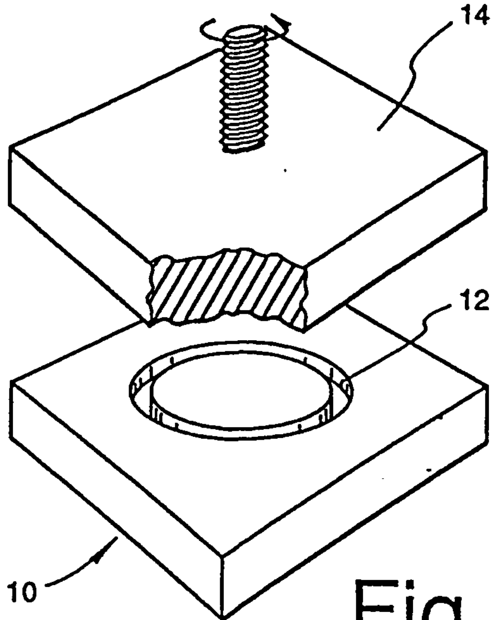

Fig. 1

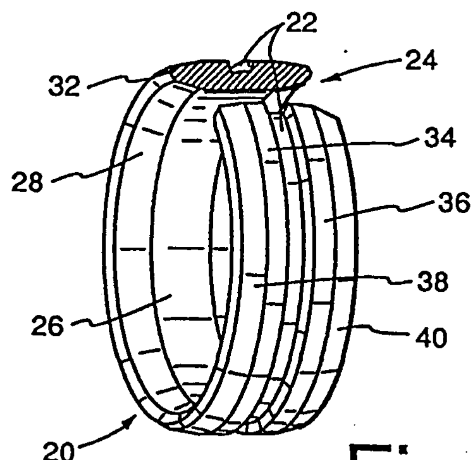

Fig. 2

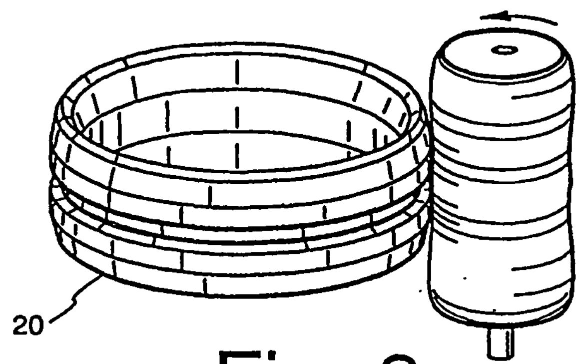

Fig. 3

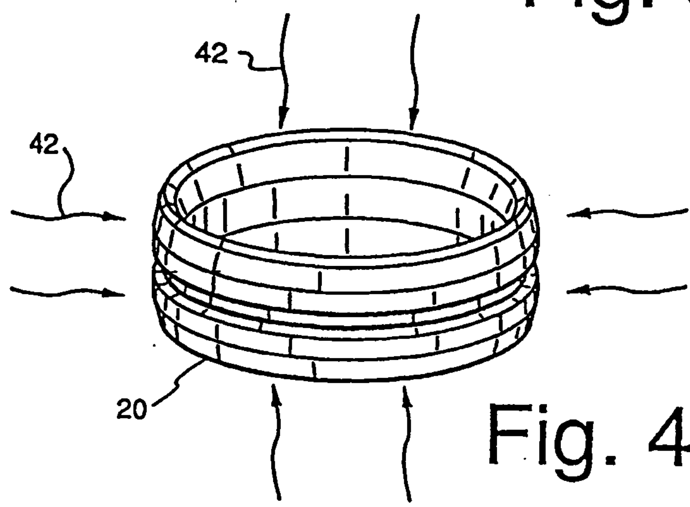

Fig. 4

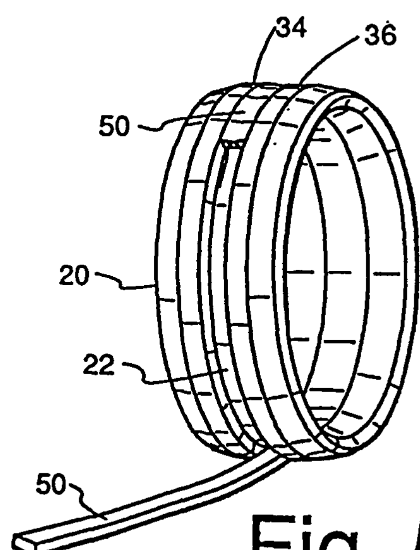

Fig. 5

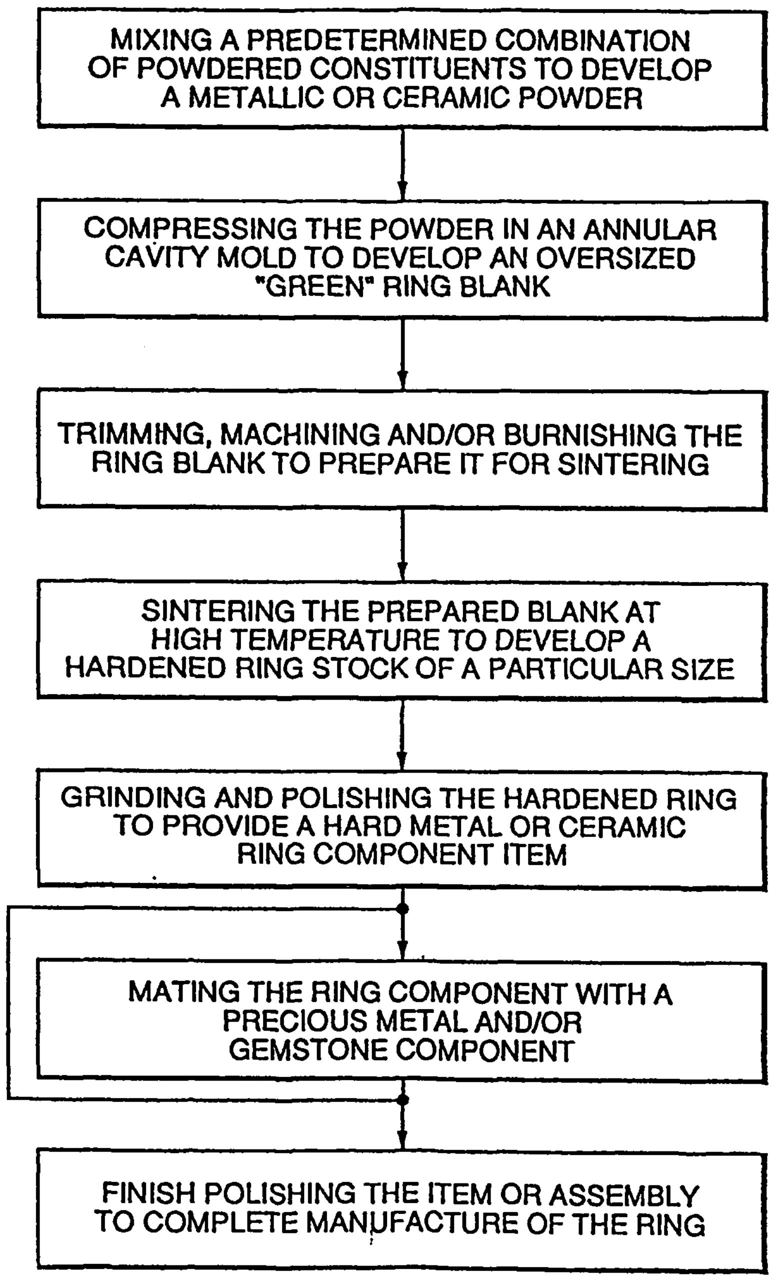
MIXING A PREDETERMINED COMBINATION OF POWDERED CONSTITUENTS TO DEVELOP A METALLIC OR CERAMIC POWDER
COMPRESSING THE POWDER IN AN ANNULAR CAVITY MOLD TO DEVELOP AN OVERSIZED "GREEN" RING BLANK
TRIMMING, MACHINING AND/OR BURNISHING THE RING BLANK TO PREPARE IT FOR SINTERING
SINTERING THE PREPARED BLANK AT HIGH TEMPERATURE TO DEVELOP A HARDENED RING STOCK OF A PARTICULAR SIZE
GRINDING AND POLISHING THE HARDENED RING TO PROVIDE A HARD METAL OR CERAMIC RING COMPONENT ITEM
MATING THE RING COMPONENT WITH A PRECIOUS METAL AND/OR GEMSTONE COMPONENT
FINISH POLISHING THE ITEM OR ASSEMBLY TO COMPLETE MANUFACTURE OF THE RING

Fig. 6

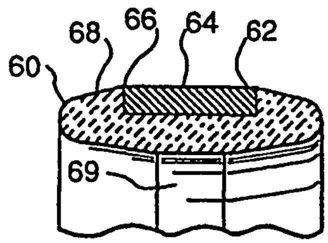

Fig. 7

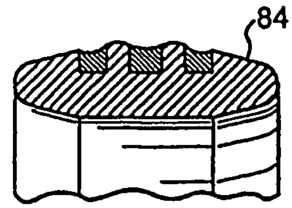

Fig. 11

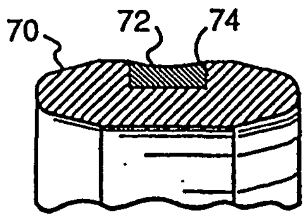

Fig. 8

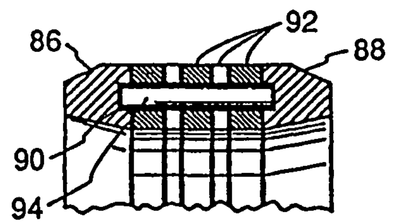

Fig. 12

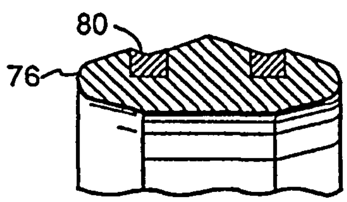

Fig. 9

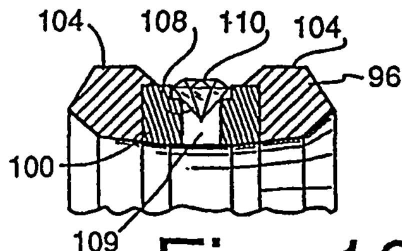

Fig. 13

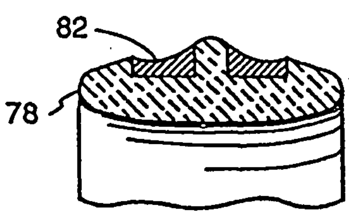

Fig. 10

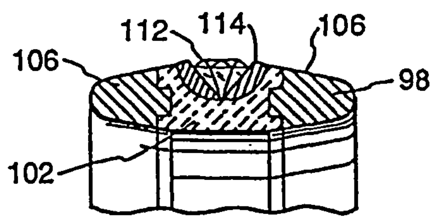

Fig. 14

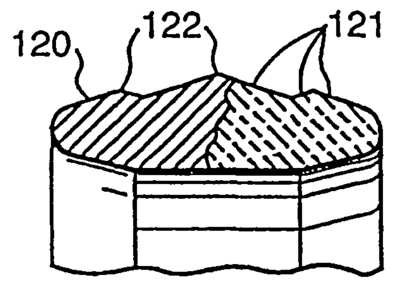

Fig. 15

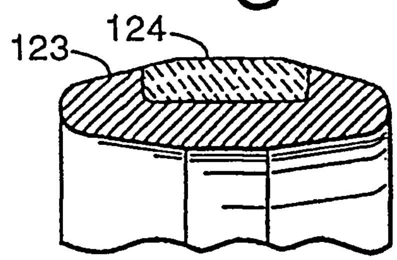

Fig. 16

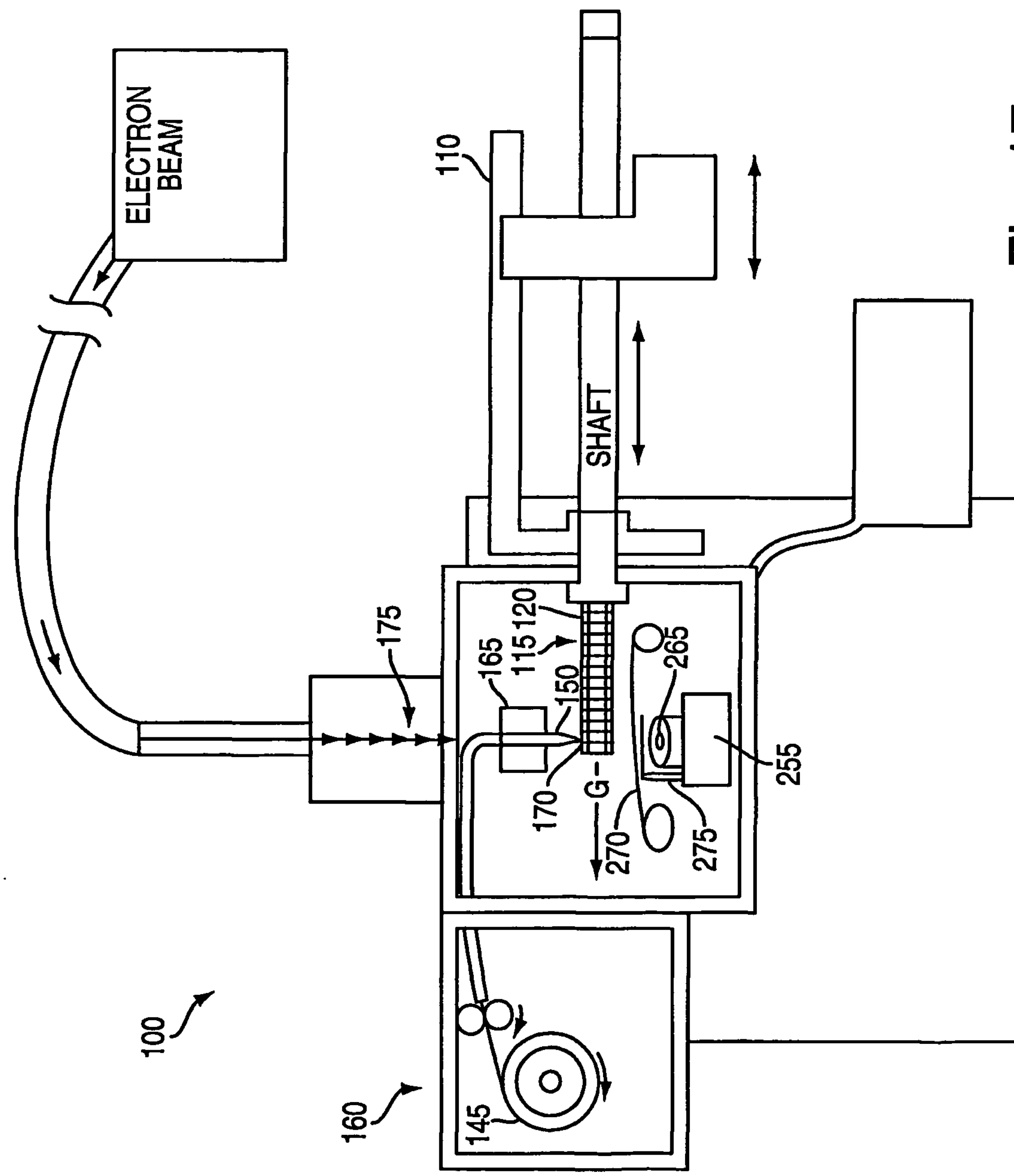
ELECTRON BEAM
110
SHAFT
175
165
115
120
150
265
170
G
255
270
275
100
160
145

Fig. 17

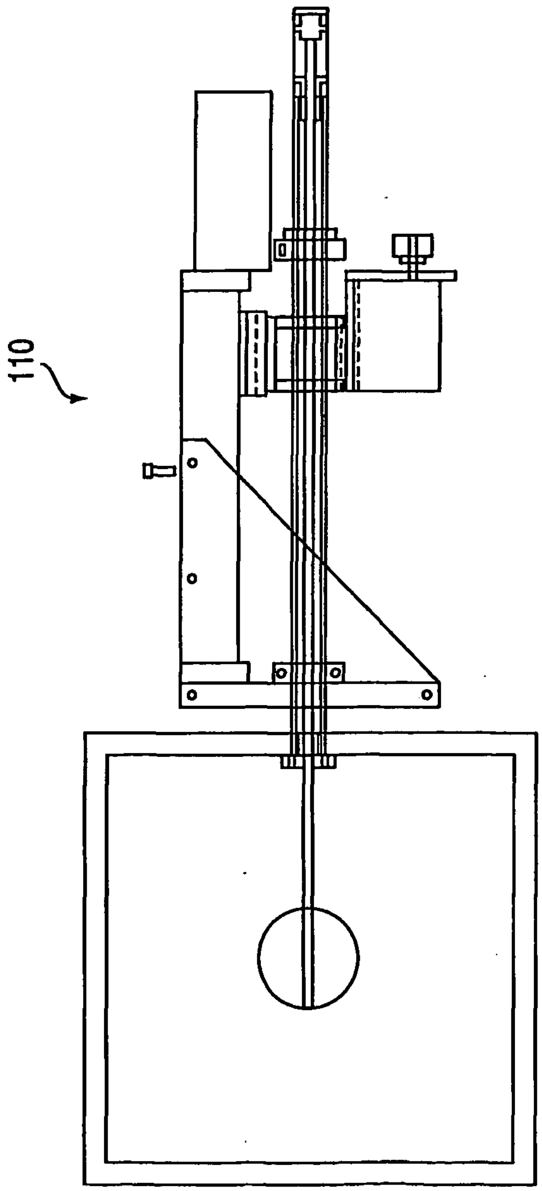

Fig. 18

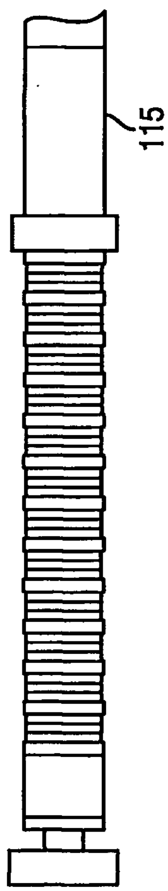

Fig. 19A

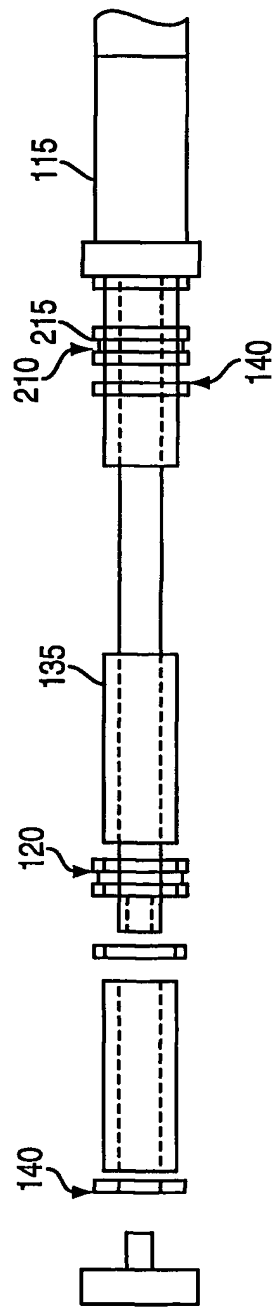

Fig. 19B

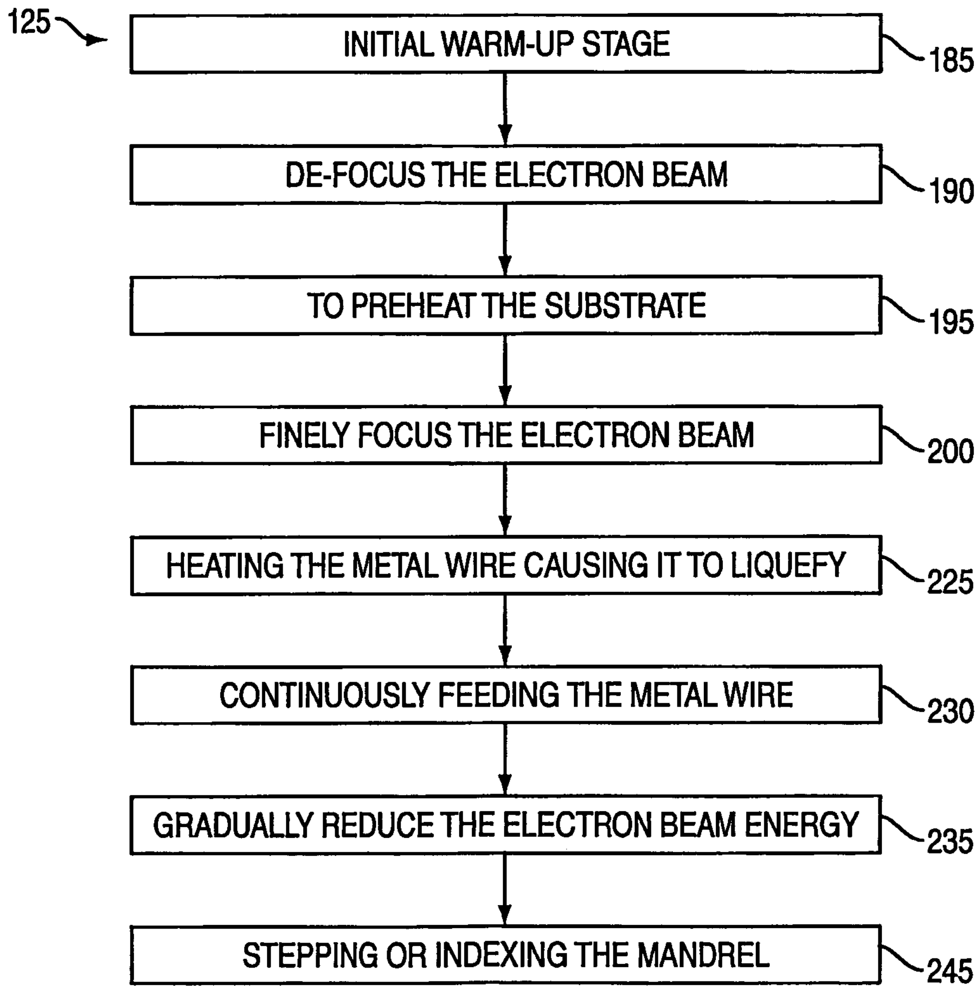
125
INITIAL WARM-UP STAGE
185
DE-FOCUS THE ELECTRON BEAM
190
TO PREHEAT THE SUBSTRATE
195
FINELY FOCUS THE ELECTRON BEAM
200
HEATING THE METAL WIRE CAUSING IT TO LIQUEFY
225
CONTINUOUSLY FEEDING THE METAL WIRE
230
GRADUALLY REDUCE THE ELECTRON BEAM ENERGY
235
STEPPING OR INDEXING THE MANDREL
245

Fig. 20

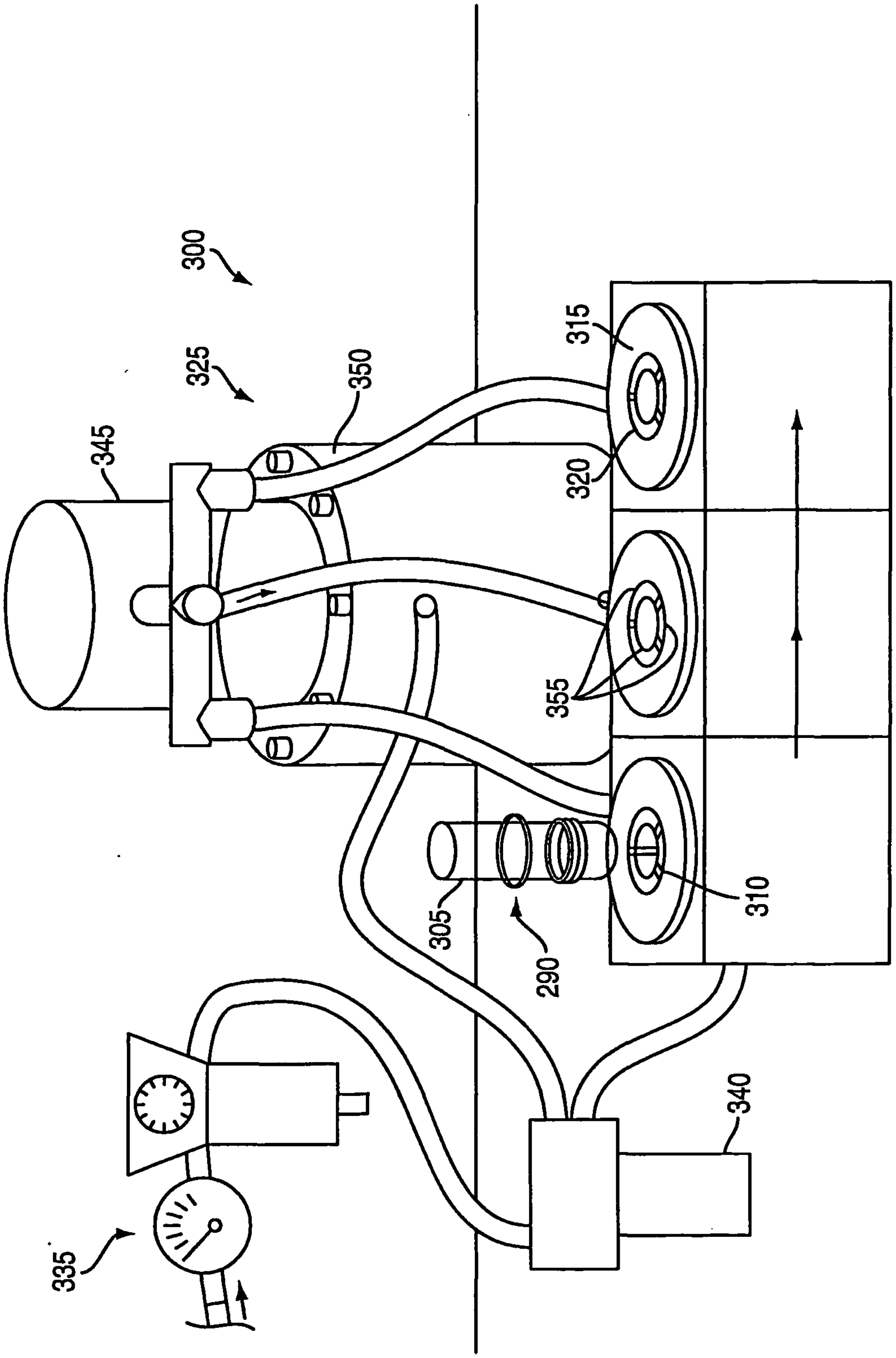

Fig. 21

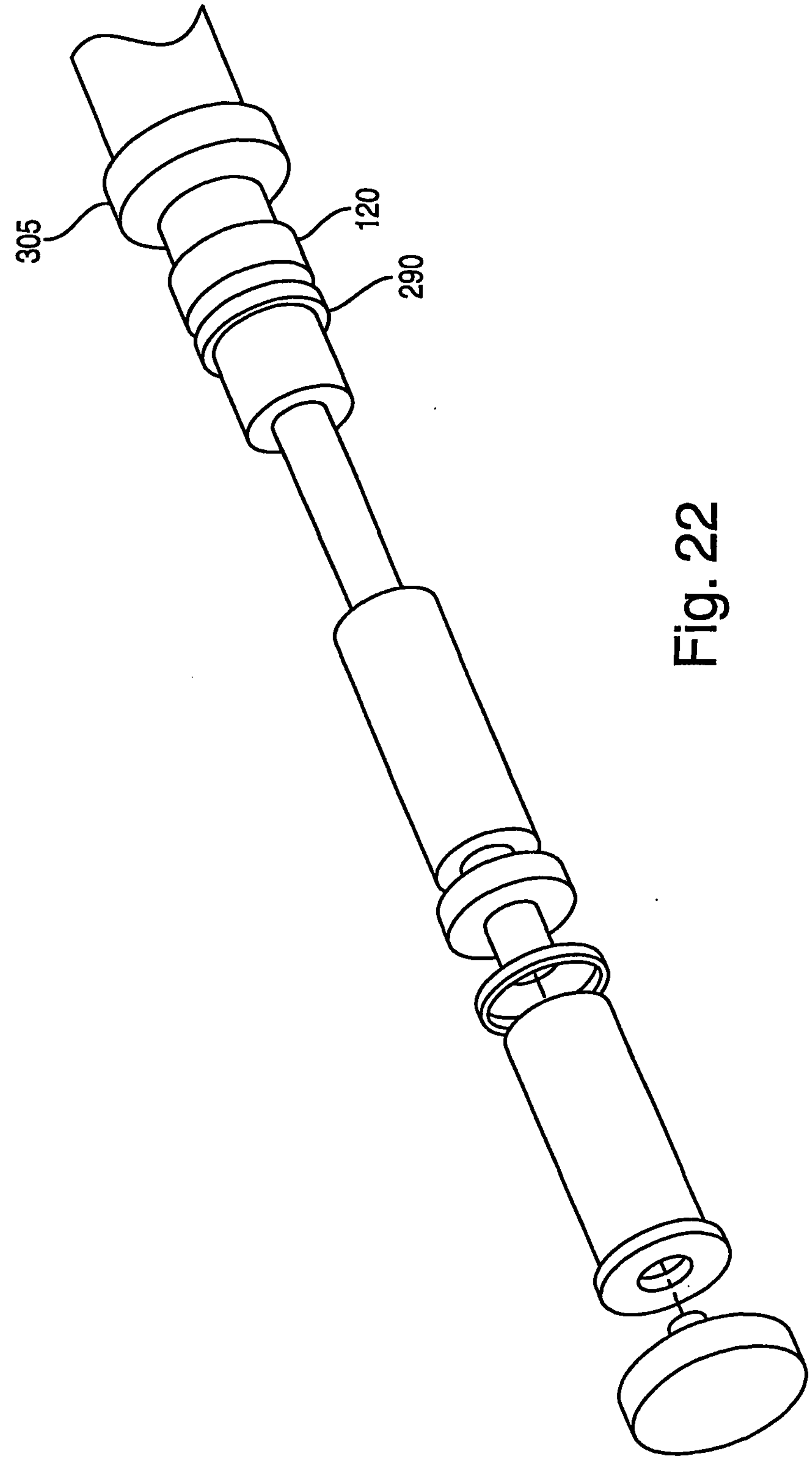

Fig. 22

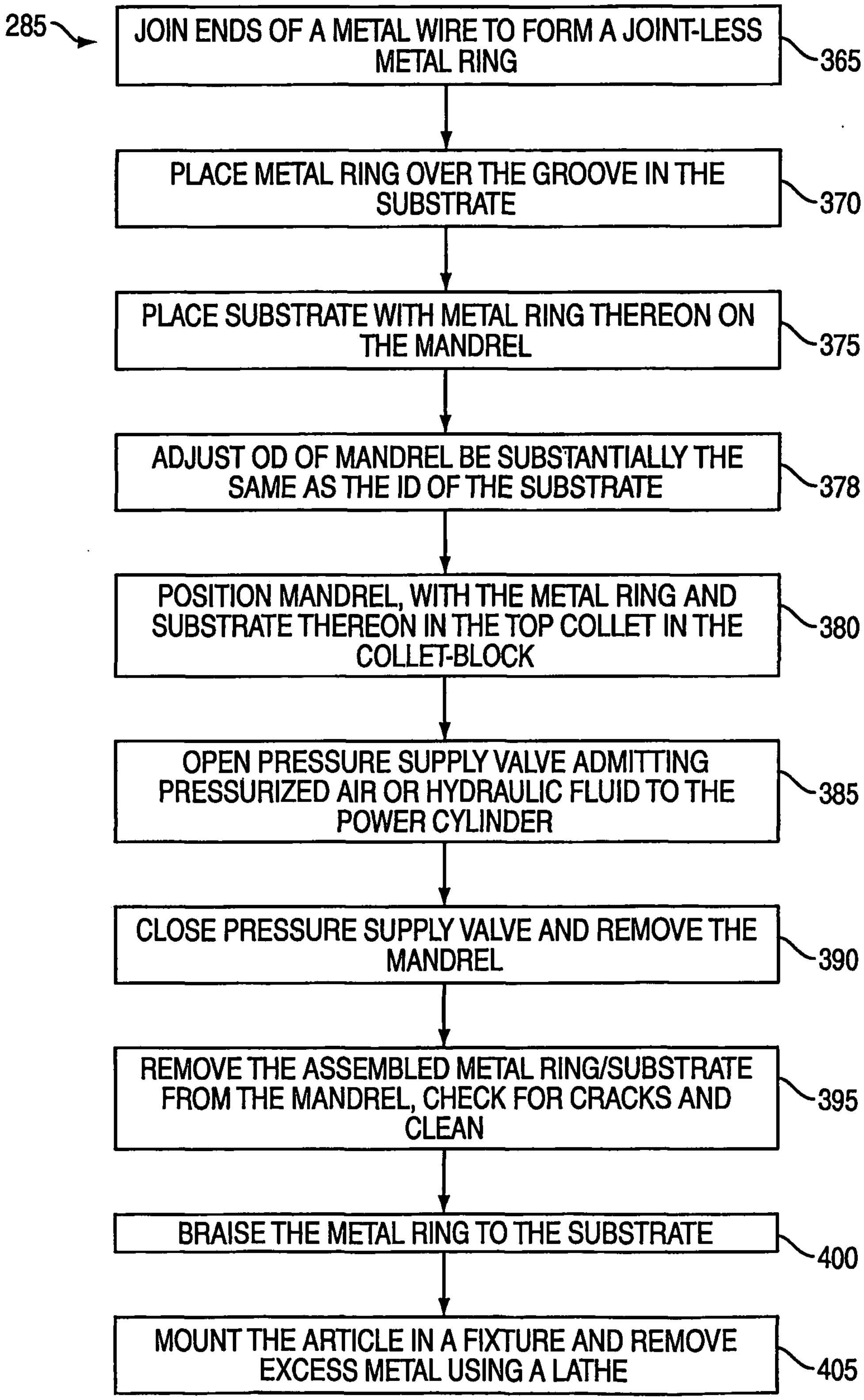
285
JOIN ENDS OF A METAL WIRE TO FORM A JOINT-LESS METAL RING
365
PLACE METAL RING OVER THE GROOVE IN THE SUBSTRATE
370
PLACE SUBSTRATE WITH METAL RING THEREON ON THE MANDREL
375
ADJUST OD OF MANDREL BE SUBSTANTIALLY THE SAME AS THE ID OF THE SUBSTRATE
378
POSITION MANDREL, WITH THE METAL RING AND SUBSTRATE THEREON IN THE TOP COLLET IN THE COLLET-BLOCK
380
OPEN PRESSURE SUPPLY VALVE ADMITTING PRESSURIZED AIR OR HYDRAULIC FLUID TO THE POWER CYLINDER
385
CLOSE PRESSURE SUPPLY VALVE AND REMOVE THE MANDREL
390
REMOVE THE ASSEMBLED METAL RING/SUBSTRATE FROM THE MANDREL, CHECK FOR CRACKS AND CLEAN
395
BRAISE THE METAL RING TO THE SUBSTRATE
400
MOUNT THE ARTICLE IN A FIXTURE AND REMOVE EXCESS METAL USING A LATHE
405

Fig. 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15660

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	C. on of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 3,606,766 A (J.S. HILL) 21 September 1971 (21/09/71), see abstract; col. 1, line 40 - col. 2, line 29 and 60-63, and claims.	17, 27 ——— 24-26
X — Y	US 3,669,695 A (ILER et al) 13 June 1972 (13/06/72), see col. 1, line 13 - 57; col. 2, line 40 - col. 3, lines 11 and 35-50; col. 4, lines 5-24, 32-43 and 60-75; col. 5, line 45 - col. 6, line 22; col. 8, line 43-75; Example 1, esp. col. 10, lines 7-50 and 60; Example 2, esp. col. 11, lines 7-62, and col. 14, lines 5-8 and 37-41.	17, 25, 27 ——— 24, 26
X — Y	US 3,409,416 A (YATES et al) 05 November 1968 (05/11/68), see the abstract; col. 8, line 70 - col. 10, line 29; col. 13, lines 5-22, Ex. 2, 3, etc.	17, 24 ——— 26

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 17 NOVEMBER 2000	Date of mailing of the international search report 04 JAN 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MARIANNE L. PADGETT Jean Proctor Paralegal Specialist Telephone No. (703) 308-2336

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15660

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,090,284 A (KRAFT) 23 May 1978 (23/05/78), see the abstract; figures, esp. 2 and 4; col. 4, line 68 - col. 5, line 33; and claims 1, 3-4, 6-8 and 10-11.	17-18, 23 -------- 21
Y	US 2,016,679 A (M.A. MAYER) 08 October 1935 (08/10/35), see figures; col. 1, lines 1-17 and col. 2, lines 3-55+.	18, 22-23, 25-27
Y	US 2,027,060 A (NIVEN et al) 07 January 1936 (07/01/36), see figures, col. 2, lines 10-15 and 31 - col. 3 (page 2), line 32.	10-16
X --- Y	CHOATE, Sharr. Creative Gold - And Silver Smithing: Jewelry, Decorative Metalcraft. New York: Crown Publishers, Inc. 1970, excerpts pages 58-68, 139-150, 165-170, 188 and 245-264, especially p. 142-144, 60, 64-65.	1, 4 -------- 3, 5, 6, 8-16, 18-23
Y	US 3,725,634 A (LANE) 03 April 1973 (03/04/73), see abstract; figures; col. 1, line 56 - col. 2, line 65; and col. 3, lines 10-42.	1-7
Y	US 4,549,058 A (DEL MASTRO et al) 22 October 1985 (22/10/85), see abstract; Figures; col. 1, lines 27-45; col 2, lines 5-30 and claims 1-3.	1-7
Y	US 4,281,235 A (PELOQUIN) 28 July 1981 (28/07/81), see abstract, figrues 5-6 and 8-9; col. 1, lines 48 - col. 2, line 36.	1-9
Y	US 4,387,627 A (AVEZOU) 14 June 1983 (14/06/83), see abstract; figures; and col. 2, lines 10-50.	1-7
X --- Y	US 3,417,223 A (K.H. STEIGERWALD) 17 December 1968 (17/12/68), see the figures; abstract; col. 2, lines 30 - col. 3, line 46.	1 -------- 2-7
A	US 5,462,772 A (LEMELSON) 31 October 1995 (31/10/95), see entire document, espeically abstract and figures.	1-9 and 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15660

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15660

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (7):

A44C 9/00, 27/00; B23P 15/00; B22D 18/02, 19/04, 19/16; B23K 5/10, 9/04, 15/10, 15/04; B05D 3/06

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

63/3, 15, 15.3, 26; 29/8, 888.072, 896.4, 896.411, 896.412; 148/524, 525, 528; 164/494, 469; 219/58, 76.1, 121.14, 121.15, 121.17, 129; 228/165, 168, 229, 244; 427/551, 552, 596, 597, 286

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

63/3, 15, 15.3, 26; 29/8, 458, 525.14, 507.508, 527.6, 888.072, 888.074, 896.4, 896.411, 896.412, DIG 29, DIG 3D, DIG 31; 148/516, 522, 524, 525, 528, 538; 164/91, 95, 97, 469 470, 494, 495; 219/56, 58, 76.1, 76.14, 121.13, 121.14, 121.15, 121.16, 121.17, 129; 228/120, 165, 168, 229, 244, 245, 246, 247; 427/551, 552, 553, 554, 556, 559, 596, 597, 189, 256, 284, 286

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claim(s)1-14 & 19, drawn to inlaying a second material in an object of a first material via a heating technique.
Group II, claim(s) 17-27, drawn to compression molding and sintering powder to form an object.

The inventions listed as Groups I & II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: The method of manufacture of the article or object, which may or may not be subsequently processed by being inlaid, is a special technical feature which is independent of any subsequent processes applied thereto. Likewise, the special technical feature of filling depressions on an article via a heating technique, such as electron beam, is unaffected by whether that article was formed by machining, casting, powder molding, etc...